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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE

BERKELEY MEETING

AT

THE UNIVERSITY OF CALIFORNIA

BERKELEY, CALIFORNIA

July 12–13, 1946

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BULLETIN

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AMERICAN PHYSICAL SOCIETY

BERKELEY MEETING, JULY 12–13, 1946

THE 273rd meeting of the American Physical Society will be held at the University of California, Berkeley, California, on Friday, July 12, and Saturday, July 13, 1946. There will be four sessions. The two sessions on Friday will be held in Room 212 of LeConte Hall, starting at 9:30 A.M. and 2 P.M., respectively. They will be devoted to contributed papers, except for an invited paper by Richard A. Ogg, Jr., of Stanford University, entitled "Experimental Demonstration of Electrical Superconductivity in Metal-Ammonia Solutions," which will open the afternoon session.

The Saturday morning session will be held in Room 210 of LeConte Hall, starting at 9:30 A.M. and will be devoted to a Symposium on the Production and Use of High Energy Particles. All five speakers are members of the physics department at Berkeley and they will discuss particularly the work of the Radiation Laboratory at Berkeley.

The Saturday afternoon session will start at 2:00 P.M. in Room 212 of LeConte Hall and will be devoted to the remainder of the contributed papers.

No definite arrangements for luncheon have yet been made, but out-of-town members will be cared for, in one way or another.

Prospective Meetings of the Society

274. New York, September 19–21, 1946. (Meeting limited to special topics.)
275. Minneapolis, November 29–30, 1946.
276. Winter meeting on the West Coast. (To be arranged.)
277. New York, January 23–25, 1947. (1946 Annual Meeting.)
278. Washington, May 1–3, 1947.

General Rules Relating to Papers

No paper may be accepted for presentation at any meeting of the Society unless the title and an abstract of the paper are delivered to the office of the American Physical Society not later than the closing date stated in the printed call for that meeting.

The time allowed for the oral presentation of a contributed paper is ten minutes at the most.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited to the one first named in its title.) For each paper on this programme the Secretary indicates a session at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in shortened form, or may read it by title.

Titles and abstracts of the papers to be presented are given in the following pages. Proofs of the abstracts have not been submitted to the authors. After submission of proof the abstracts will be published in an early number of *The Physical Review*.

R. T. BIRGE,
Local Secretary for the Pacific Coast,
University of California,
Berkeley, California

PROGRAMME

FRIDAY MORNING AT 9:30

Room 212, LeConte Hall

A1. A Method for Measuring Small Changes in Alternating Magnetic Fields. WILSON M. POWELL, *Radiation Laboratory, University of California.*—The magnetic field at the orbit of the electrons in a betatron or a synchrotron must sweep through zero at all points of the orbit at the same time. A small search coil with effective area 1300 cm² was placed in a 60-cycle magnetic field of 4000 oersteds. The voltage was integrated by an *R-C* circuit and the resulting signal was fed to the vertical plates of an oscilloscope. The horizontal sweep was fed by a sinusoidal voltage, which was phased so as to produce a diagonal line on the oscilloscope. A second search coil of slightly larger area connected in series with the first was placed in the field and rotated till the line became horizontal. The second coil bucked out most of the signal from the first coil. When the amplification of the vertical amplifier was increased, this line broadened out into an ellipse whose vertical minor axis gave a measure of the difference in the magnetic fields threading the two coils when the field is passing through zero. Variations of one-tenth of an oersted could be detected in this way. This work was done under the auspices of the Manhattan District.

A2. Magnetic Fields Due to Dee Structures in a Synchrotron. ARNOLD F. CLARK, *Radiation Laboratory, University of California.*—The method described in the foregoing abstract was used to measure the out of phase fields due to eddy currents in the metal dee. The variations due to the size of the dee and to the width of the laminations will be reported. Experiments and calculations show how the magnetic focusing is altered in different parts of the dee because of the eddy current fields. The field as a whole is decreased but can be increased by a d.c. winding around part of the yoke. The variation of the vertical field with radius is changed, and horizontal field components are added. The measurements were checked by observing the time of reversal of flux in small permalloy strips placed at different points in the magnetic field. The difference in the time of reversal between two points in the magnet multiplied by the rate of change of the field gives the difference in the magnetic fields at the two points due to the out of phase components. This work has been carried out under the auspices of the Manhattan District.

A3. Momentum and Specific Ionization of 25–100 Kv Electrons. CARL E. NIELSEN, *University of California, Berkeley.*—There is some indication of disagreement between the relativistic calculation and observed specific ionization of 25–100 kv electrons, but existing data do not permit a reliable comparison. For this reason, and for evaluation of meson mass by ionization and curvature measurement, study of electron ionization is in progress. Ionization is measured by droplet count technique. Momentum is measured by curvature in a magnetic field. Multiple scattering at these energies normally results in large momentum uncertainty because the field usable is limited by the necessity of keeping the radius measurable. The field can be increased if one photographs perpendicular to the field axis. Tracks then describe helices; their plane projections are sine curves whose "amplitude" and "wavelength" give the momentum. Since the tracks extend along the field, their radius of curvature may be small, permitting 1000 oersted or more and reducing the error from scattering. Further gain in accuracy results from the large track length used. One may consequently expect accuracy about ten times that of the usual arrangement with camera and field axes parallel. In the new method the track length depends merely upon axial distance and helix pitch, making stereoscopic photography unnecessary and simplifying track length measurements.

A4. Range-Momentum Relationship for Cosmic-Ray Mesotrons. W. B. FRETTER, *University of California, Berkeley.*—The range of mesotrons in lead as a function of their momentum is determined in an experiment similar to that of J. C. Street* in which two simultaneously expanded counter-controlled cloud chambers are used. The upper chamber is in a magnetic field of 5300 gauss, while the lower, which is vertically in line, contains eight ½-inch thick lead plates. Approximately 7 percent of the mesotrons which trip the counters are stopped in the lower chamber. If ionization losses alone are involved in stopping the particles, this experiment gives information on the masses of the stopped mesotrons. If, however, nuclear processes are important, straggling may be expected, which would give an apparent distribution in masses. Ionization drop counts as well as curvature measurements are made in the upper chamber so that protons stopping in the lead are easily recognized. Electrons make showers in the lower chamber. Preliminary results indicate that the straggling is probably not as violent as that reported by Street.

* J. C. Street, J. Frank. Inst. 227, 765 (1939).

A5. Description of a Frequency Modulated Cyclotron and a Discussion of the Deflector Problem. E. J. LOFGREN AND B. PETERS, *Radiation Laboratory, University of California.*—To verify the theory of the frequency modulated cyclotron,[1,2] which provides a means of overcoming the relativistic limitations of large cyclotrons, a prototype was built using the 37-inch magnet. The variation of resonant frequency which will be caused by mass increase at large energies was here produced by a radial decrease in magnetic field. At convenient values of modulation frequency (2000 c.p.s.) the energy gain per turn is so small that

adjacent turns are only about 0.005 inch apart. Such spacing would seem to be insufficient to operate a conventional d.c. deflector since the exit strip would intercept most of the beam. Precessional motion of orbits, however, can greatly increase the change of radius per turn. This was demonstrated by bombarding a probe in the circulating beam where activity was obtained as far as 0.2 inch back from the leading edge. This fact led us to try a d.c. deflector, which successfully deflected up to 10 percent of the circulating beam of 8-Mev deuterons. This work was carried on under a Manhattan District contract.

[1] V. Veksler, J. Phys. U.S.S.R. **9**, 153 (1945).
[2] E. McMillan, Phys. Rev. **68**, 143 (1945).

A6. Frequency Modulation for Berkeley 37″ Cyclotron. K. R. MacKenzie and F. H. Schmidt, *Radiation Laboratory, University of California.*—The system consists of a transmission line terminated at one end by the single cyclotron dee and at the other by a variable capacitor operating in a separate vacuum. A voltage node occurs near the center of the line. Fifteen-kv dee voltage is produced by a grounded grid oscillator. The tubes are coupled to the dee stem by plate and filament coupling loops. Excitation phase is controlled by a capacitor in series with the filament loop. The voltage rises throughout the acceleration. The vacuum capacitor consists of a steel disk 27″ O.D. with 36 blades at its periphery rotating between a double set of stationary blades. The latter connect to the transmission line through a procelain insulator. The disk is mounted on an insulator and forms one-half of a coupling capacitor to ground, thereby eliminating moving contacts. The variable capacitor produces a modulation frequency up to 2,000 c.p.s. The frequency range is from 12 to 9.5 mc for deuterons and 24 to 18 mc for protons. This work was done under the auspices of the Manhattan District.

A7. Frequency Modulated Cyclotron Characteristics. Byron T. Wright and J. Reginald Richardson, *Radiation Laboratory, University of California.*—The beam current dependence on various operational parameters will be compared with theory; those investigated include the following. *Modulation frequency:* For each dee voltage an optimum modulation frequency exists when the average energy gain per turn required to keep the natural frequency of the ions equal to the applied frequency equals one-half the available energy gain per turn. *Pressure:* All loss caused by scattering occurs at energies <300 kv; doubling base pressure in operating range reduces beam fourfold. *Dee voltage:* Doubling dee voltage in range 3–5-kv peak triples beam for equivalent modulation frequencies. At dee voltage 11.5 kv, modulation rate 1900 cycles per second, pressure 3.6×10^{-5} mm Hg, 2.9 microamperes (d.c. average) of undeflected 8-Mev deuterons have been produced. The structure of individual beam pulses will be mentioned. Some ions start on one modulation cycle and arrive at the final radius as many as three modulation cycles later. These ions, on being lost from the acceleration of the first cycle at a certain radius, continue rotating near that radius until the next cycle, when some of them, having the proper phase, will be picked up and further accelerated. This work was done under the auspices of the Manhattan District.

A8. Efficiency of Frequency Modulated Cyclotron. Leslie Foldy and D. Bohm, *Radiation Laboratory, University of California.*—In the frequency modulated cyclotron (or synchro-cyclotron) the loss of resonance resulting from relativistic increase of mass is overcome by capture of particles into phase stable orbits,[1,2] the energy of which is adiabatically increased by a slow decrease of frequency of the dee voltage. There is, however, only a small fraction of the cycle of frequency modulation during which ions can be captured into phase stable orbits with phase oscillations of amplitude small enough to prevent particles from ever being returned to the origin. By solving the phase equation,[2] we have obtained general expressions for this fraction, which may be called the "efficiency" relative to that of a normal cyclotron. For conditions which may be realized in the 182″ cyclotron to be built at Berkeley, the maximum efficiency is about 5 percent. This work was done under the auspices of the Manhattan District.

[1] E. McMillan, Phys. Rev. **68**, 143 (1945).
[2] V. Veksler, J. Phys. U.S.S.R. **9**, 153 (1945).

A9. Cloud Chamber for Airborne Cosmic-Ray Observations. Wayne E. Hazen, *University of California, Berkeley.*—Two small cloud chamber units have been constructed for use in high altitude observations of cosmic radiation. The first consists of a chamber with a cylindrical observation volume ($3''\times6''$) containing three lead plates. Compression is obtained by a motor-driven piston, which is isolated from the ambient pressure except for an area less than one square inch. A light-weight ten-volt battery provides power for compression, as well as for illumination and camera operation. Four 32–32-cp automobile headlight bulbs provide illumination. In order to provide for long uninterrupted runs of four or five hours, a camera that holds 100 feet of film was constructed. Test flights have been successfully made to 20,000 feet. The second unit is a $1''\times8''$ diameter cylindrical chamber placed in the field of a permanent magnet that has square poles ($6''\times6''$). Model tests indicate that the 700-pound magnet will give a field somewhat greater than 1500 gauss. Preliminary photographs have been obtained. The first unit is intended for a study of the general character and relative intensities of the rays, and the second for a detailed study of particular properties, such as mesotron masses, by means of ionization-momentum measurements.

A10. A Paradox on Nuclear Isomerism. Emilio Segrè, *University of California, Berkeley.*—Suppose that a diatomic homonuclear molecule containing two nuclei obeying Bose statistics is formed and that its possible rotational states are the odd ones. If one of the nuclei is excited, the molecule ceases to be strictly homonuclear and all rotational states are allowed, in particular also the state of zero rotation. Hence, by using nuclei in the excited state and nuclei in the fundamental state, we could form molecules in the zero rotational state, and if in one of these the isomeric transition of the nucleus should occur without

alteration of the rotational state, we would have the absurdity of the homonuclear molecule in rotational state zero. According to the energy of the isomeric transition, two cases are possible. Either the energy is such that the recoil momentum from radiation emitted is insufficient to change the rotational state of the molecule, in which case the transition does not occur, or the recoil is sufficient to change the rotational state. In the first case the paradox is removed by the fact that the transition does not occur; in the second, by the concurrent excitation of the molecule.

A11. The Nuclear Reaction (*p, pn*). J. REGINALD RICHARDSON AND BYRON T. WRIGHT, *Radiation Laboratory, University of California.*—The 16-Mev protons produced by the 37-inch FM cyclotron have been used to bombard several elements. Evidence for the occurrence of the new reaction (*p, pn*) has been obtained in the cases of copper and antimony. In particular the 12.8-hour period in copper has been obtained, presumably from the reaction Cu^{65} (*p, pn*) Cu^{64} and the 16-minute period in antimony, presumably from the reaction Sb^{121} (*p, pn*) Sb^{120}. The usual precautions against neutron activation have been observed. A preliminary excitation curve has been obtained in the case of copper. It is a steeply rising curve, with a threshold at about 13-Mev proton energy. This work has been carried out under the auspices of the Manhattan District.

A12. Isotopic Absorption of Slow Neutrons in Cadmium. B. J. MOYER, B. PETERS, AND F. H. SCHMIDT, *Radiation Laboratory, University of California.*—Cadmium samples enriched in specific isotopes by a mass spectrograph are being studied with respect to thermal neutron absorption.[1] A quick survey of the isotopic absorptions was made by comparing the slow neutron absorption of solutions of $CdSO_4$ made from the enriched samples with that of a normal $CdSO_4$ solution. A spherical bulb containing the solution under test was inserted in a neutron atmosphere produced by a Ra-Be source in paraffin. Supported at the center of the bulb were two indium detectors, one of which was cadmium shielded to measure the fast-neutron-produced activity. Only the normal Cd and the Cd(113) solutions showed measurable absorption. The Cd(113) absorption equalled that of the normal solution when ratio of concentrations was 1 to 6.0 ± 0.4, respectively. It is concluded that the strong absorption in Cd is due to resonance capture in Cd(113). Since the concentration of 113 in normal Cd is 1 part in 8, it appears that the sample enriched in 113 has a concentration of 70–80 percent in this isotope. Mass spectrograph analysis of the sample is to be made. In progress are measurements of the Cd(113) cross section employing electroplated deposits of the 113 sample on thin Pt. This work was carried out under the auspices of the Manhattan District.

[1] H. A. Bethe, Rev. Mod. Phys. 9, 151 (1937).

A13. The Local Secretaryship for the Pacific Coast. KARL K. DARROW, *Secretary, American Physical Society.*—Laudatory remarks concerning the eximious services of R. T. Birge as Local Secretary of the American Physical Society for the Pacific Coast.

FRIDAY AFTERNOON AT 2:00

Room 212, LeConte Hall

Invited Paper

B1. Experimental Demonstration of Electrical Superconductivity in Metal-Ammonia Solutions. RICHARD A. OGG, JR., *Stanford University.* (30 min.)

Contributed Papers

B2. X-Radiation and Internal Conversion from Ru+*d*. D. T. EGGEN AND M. L. POOL, *Ohio State University.*—By the use of a curved crystal x-ray spectrograph,[1] characteristic x-ray radiations have been obtained of masurium, ruthenium, and rhodium—the products of ruthenium bombarded with 10-Mev deuterons. The intensities of the x-rays were plotted as a function of time in order to show the type of transmutation and period associated with each radiation. When the beta-particles were removed by a magnetic field, data were taken on a Wulf electrometer and ionization chamber, which gave a reading of the x-rays and gamma-rays. On subtraction of the gamma-rays, a decay of the x-rays only was obtained, which was used to establish the periods in which the various x-rays occur. At the same time beta-ray spectrograms were taken that show energies associated with the internal conversion of gamma-rays in certain isotopes of masurium, ruthenium, and rhodium. These energies were observed over a range from 25 kev to 125 kev.

[1] J. E. Edwards, M. L. Pool, and F. C. Blake, Phys. Rev. 67, 150 (1945).

B3. Theory of Continuous X-Ray Spectra from Thick Targets. PAUL KIRKPATRICK, *Stanford University.*—The Sommerfeld theory of the production of continuous x-rays by bombarding atomic nuclei with electrons predicts

radiation energies which, to a rather rough approximation, are directly proportional to the square of the target atomic number Z and inversely proportional to the energy of bombardment. When spectrum bands of equal frequency width are considered, the variation of radiation energy with frequency is relatively slight and may be neglected in the first approximation. Upon combining the Sommerfeld predictions in this form with the electron energy-loss formula of Thomson and Whiddington, and the energy-loss measurements of Terrill, we obtain the conclusion that the total thick-target radiation energy (ergs) in a frequency interval $d\nu$ at ν per bombarding electron is $8\times10^{-51}Z(\nu_{max}-\nu)d\nu$, where Z is the target atomic number. This expression agrees with the observations of Wagner and Kulenkampff with respect to energy distribution and Z dependence. Agreement with experiment is not improved by using a less approximate form of continuous-spectrum theory or a presumably more accurate energy loss theory.

B4. Acceleration of Stripped Light Nuclei in the Cyclotron. HERBERT YORK, ROGER HILDEBRAND, THOMAS PUTNAM, AND J. G. HAMILTON, *Radiation Laboratory, University of California.*—Experiments have been done to produce accelerated stripped light nuclei with the 60″ Berkeley cyclotron for use in nuclear experiments. Two types of sources have been investigated: an arc source such as that normally used in cyclotrons and a spark source similar to that used in spectroscopic investigations of highly ionized atoms. Typical yields from an arc source are 1000 $C^{13,+6}$ 146-Mev ions per second and 100,000 $C^{12,+6}$ 135-Mev ions per second. Experiments with C^{+6} have previously been done at lower energies with the 37″ cyclotron by L. W. Alvarez,[1] and with the 60″ cyclotron by Tobias and Segrè,[2] and Condit,[3] who also reported O^{+8}. This work has been done under the auspices of the Manhattan District.

[1] L. W. Alvarez, Phys. Rev. **58**, 192 (1940).
[2] C. A. Tobias, Ph.D. thesis, University of California, 1941.
[3] R. I. Condit, Phys. Rev. **69**, 301 (1942).

B5. Forces on Ferromagnets Through Which Electrons Are Moving. D. L. WEBSTER, *Stanford University.*—Wannier[1] calculated the forces on electrons shot through ferromagnets, finding them notably less than they would be if the average field encountered by an electron was B, because such electrons avoid the magnetization electrons or push them away electrostatically, thereby avoiding the strongest fields. At low speeds the average is roughly half B. If one applies Wannier's equation to conduction electrons, they should experience only about half the force $I\times B$, now usually assumed and apparently confirmed by the torques on current-carrying magnets measured by Zeleny and Page.[2] It will be proved that the difference is made up by forces on the magnetization electrons, caused by the magnetic fields of the conduction electrons. About half the measured force on the magnet, therefore, acts on conduction electrons, and the rest on magnetization electrons. When a fast electron penetrates a magnet and is deflected by Wannier's force, neighboring magnetization electrons experience forces whose resultant has the same direction. The sum of this resultant and Wannier's force equals the force which the fast electron alone would experience if its average field was B.

[1] G. Wannier, Phys. Rev. **67**, 364 (1945).
[2] J. Zeleny and L. Page, Phys. Rev. **24**, 544 (1924).

B6. Reduction of Spherical Aberration in Strong Magnetic Lenses. L. MARTON AND K. BOL, *Division of Electron Optics, Stanford University.*—The primary limiting factor to the resolving power of the transmission type magnetic electron microscope, at present, is the spherical aberration produced by the objective lens. Preliminary calculations based on an extension of Glaser's[1] treatment show, however, that compound instead of single, strong lenses may be used advantageously in reducing the aberration. Such a system, in analogy to light optics, may consist of a first strong component forming a virtual image and one or more much weaker lenses to convert it into a real image. For equal magnification such a compound system can show a reduction of the spherical aberration of at least 10 percent as compared to that produced by a single, strong lens.

[1] W. Glaser, Zeits. f. Physik **117**, 285 (1941).

B7. Particle Scattering Camera. S. RUBIN, *California Institute of Technology (Introduced by William Fowler).*—A particle scattering camera for measuring the angular distribution of ionizing particles emitted or scattered by various targets has been constructed for use with the 2-Mev electrostatic generator. It is adaptable to either solid or gas targets, with means for measuring beam current to the target, for determining cross sections. Using one 2″×4″ photographic plate, one may obtain a 20°–160° angular range, with ±1° resolution. Thin solid targets will be used, whenever possible, to obtain maximum yield at each angle for a given angular resolution and beam energy resolution, since emitted particles at each angle come from the entire thickness of a solid target, but only from that portion of a gas target defined by the exit aperture. The camera is a cylindrical vacuum tank, 6″ diameter, 1½″ wide, with removable end plates, one of which carries the photographic plate holder. The target is ½″ above the plane of the plate, so that emitted particles enter the emulsion nearly parallel to its surface. The beam axis is perpendicular to the cylinder axis and 1″ off center. Coaxial with the beam are upper and lower flanges on which the target, target current shield, beam collimating apertures, and alignment sylphon joint are mounted.

B8. Measurement of Electric Field Strength in a Cavity Resonant at 200 mc. WOLFGANG K. H. PANOFSKY, *Radiation Laboratory, University of California.*—Two methods are described for measuring electric field strengths of the order of 25 kv/cm in a resonant cavity. The cavities are excited at frequencies in the neighborhood of 200 mc/sec. by high powered oscillators pulsed at a repetition rate of 15 p.p.s. with a pulse duration of 250 microseconds. One method consists of measuring the magnetic field inside the cavity by means of a loop method. The electric field is then computed by using the theoretical field distribution

inside the cavity. The other method consists of measuring the electrostatic force produced on the diaphragm of a condenser microphone. This diaphragm is placed perpendicular to the direction of the electric field at the end of the cavity in such a way as not to disturb the field distribution. The diaphragm frequency response is adjusted to follow the build-up of field in the cavity faithfully. These techniques were developed to obtain design data for the construction of a linear accelerator. This work was done under the auspices of the Manhattan District.

B9. Methods of Driving a High Q Cavity with Many Self-Excited Oscillators. J. R. WOODYARD, E. A. MARTINELLI, WILLIAM TOULIS, AND WOLFGANG K. H. PANOFSKY, *Radiation Laboratory, University of California.*—The problem considered is that of driving a long cavity resonator to be used as a linear accelerator, in the lowest longitudinal electric mode, by means of a large number of oscillators. Special problems are encountered when the resonator is many wave-lengths long and the field is to be without nodes as is the case here. Additional questions of oscillator buildup are introduced because the oscillators are pulsed. These problems were solved by methods which will be described. By properly loading each oscillator it was found that synchronization could easily be made to occur over a comparatively large range of tuning, and that the electric field strength in the cavity resonator increased with the square root of the number of driving oscillators. This work was done under the auspices of the Manhattan District.

B10. Drift Tubes for Linear Proton Accelerator. FRANK OPPENHEIMER, LAWRENCE H. JOHNSTON, AND CHAIM RICHMAN, *Radiation Laboratory, University of California.*—In the proposed accelerator, protons are to be accelerated down the axis of a resonant cavity, and shielded from the reversed electric field every half cycle, by passing through "drift tubes." The protons will gain an energy $V=V_{max}$ $(\sin \pi\alpha/\pi\alpha)$ where α is the fraction of the cycle during which the particles are not in a field-free region. Since V has a maximum for $\alpha=0$, the criterion for the length of the accelerating gap is that the field strength between drift tubes be not too great. We have chosen a value of $\alpha=0.25$ as a reasonable compromise and have investigated the shapes of drift tubes which satisfy this condition. The proposed accelerating system may be considered as a number of coaxial reentrant cylindrical cavities placed in line, with the conducting planes normal to the axis removed. The lengths of these equivalent cavities will vary with the particle energy, and will equal $\beta\lambda$. We have made variable model cavities at 3000 megacycles to investigate the relationship between drift tube diameter, α and β, for constant frequency, f, and constant outside cavity diameter, D. We have found an approximately linear relationship between drift tube diameter and β, at constant α, f, and D, for β between 0.09 and 0.3. Details of these measurements and other considerations of drift tube design will be given. This work was done under the auspices of the Manhattan District.

B11. Synchrotron Radiofrequency System. A. C. HELMHOLZ, J. V. FRANCK, AND J. M. PETERSON, *Radiation Laboratory, University of California.*—The 47.7-mc radiofrequency system for the 300-Mev Berkeley synchrotron will be described. The electrons will be accelerated both on entering and on leaving a laminated C-shaped electrode, occupying approximately 135 degrees of the electron orbit. The electrode is supported by six coaxial lines, extending radially outward. Five of these lines are terminated at the voltage nodes by ground planes, and the stubs thus formed are tuned over a small frequency range by means of rotating paddles which vary the inductance. The sixth line is electrically a half-wave-length. It couples the radiofrequency power from the grounded grid type oscillator using a medium mu water-cooled triode to the accelerating electrode. Radiofrequency excitation for the filament of the tube is obtained from a tap near the node of the half-wave-length line. This coaxial line is folded so that the tap point is physically close to the filament and forms with the oscillator a compact structure. The necessary pulsing of the oscillator will be discussed. This work was done under the auspices of the Manhattan District.

B12. Application of the Dynamical Theory of Currents to Cavity Resonators.* ALFREDO BAÑOS, JR.,** *Radiation Laboratory, Massachusetts Institute of Technology.*—The equivalent circuit of a cavity resonator is set up by applying the Lagrangian equations of dynamics to the normal coordinates of an electromagnetic resonator. The chosen coordinates are the charges proportional to the expansion coefficients in the series development of the electric displacement vector within the cavity as expressed in terms of its normal modes which, in turn, are first established for the unperturbed cavity; that is, for a non-dissipative cavity, devoid of free charge and conduction current distributions, in the absence of the external exciting circuit. Once in possession of the resonator coordinates, the effect of the wall losses and of the external circuit is obtained by including in the Lagrangian equations the additional terms required to specify these perturbations. Other perturbations may be similarly treated by an obvious extension of the method. Finally, the equivalent network whose response is identical to that of the *actual* resonator is readily constructed, by inspection, from the set of simultaneous differential equations governing the time variations of the resonator coordinates. Explicit formulas are given for the self- and mutual parameters of the equivalent circuit.

* Paper based on work done for the OSRD under contract OEMsr-262 with the Massachusetts Institute of Technology.
** Now at the University of California, Los Angeles.

SATURDAY MORNING AT 9:30

Room 210, LeConte Hall

Invited Papers

The Production and Use of High Energy Particles

S1. Why Are We Interested in High Energy Particles? J. ROBERT OPPENHEIMER, *University of California.*

S2. The Experimental Problem of Accelerating Charged Particles. ERNEST O. LAWRENCE, *University of California.*

S3. The Design of a Linear Accelerator for Protons. LUIS W. ALVAREZ, *University of California.*

S4. The Synchrotron. EDWIN M. MCMILLAN, *University of California.*

S5. The 184" Cyclotron. R. L. THORNTON, *University of California.*

SATURDAY AFTERNOON AT 2:00

Room 212, LeConte Hall

Contributed Papers

C1. Excitation of Plasma Oscillations. D. BOHM, *Radiation Laboratory, University of California.*—A theory of plasma oscillations has been developed for conditions in which special groups of electrons moving with much higher than thermal speeds are present. The first case considered was that of a beam of fast electrons injected into the plasma from a cathode. If the electron velocity is slightly above the phase velocity of plasma wave, the electron beam loses kinetic energy to the wave, which is therefore excited. The maximum amplitudes of oscillation for given conditions can easily be calculated. The second case studied was that of a plasma containing a group of fast electrons moving in random directions such as might be generated in the process of ionization. Excitation of plasma waves here is the result of the drop in wave velocity with dropping plasma density as the boundary surface is approached. Such a wave can abstract energy from electrons of a wide range of velocities, and thus provide an additional mechanism for bringing the system to equilibrium. The excitation of such waves is offered as an explanation of the anomalous scattering of fast electrons in a plasma, and of the unexpectedly rapid rate at which electrons come to the Maxwellian distribution.[1] This work was done under the auspices of the Manhattan District.

[1] Langmuir, Phys. Rev. **26**, 585 (1929); Dittmer, Phys. Rev. **28**, 507 (1926).

C2. Afterglows and the Upper Atmosphere. JOSEPH KAPLAN, *University of California, Los Angeles.*—The various nitrogen afterglows which have been studied by the writer have made it possible to produce in the laboratory nearly all of the modifications of molecular and atomic oxygen and nitrogen that are present in the earth's upper atmosphere. The early recognition by the writer, that the phenomena of excitation and of quenching in the upper atmosphere might receive their explanations through studies of afterglow processes, and the increasing interest in the physics of the upper atmosphere were responsible for the decision to continue these experiments on an intensive scale. A number of preliminary results of current experiments will be reported in order to indicate the direction of these renewed studies. In particular attention will be called to some recent conclusive results regarding the roles played by atomic nitrogen and nitrogen molecular ions in auroral afterglows and in the upper atmosphere.

C3. Internal Waves in the Ocean.* C. W. UFFORD, *U. S. Navy Electronics Laboratory, San Diego.*—When the density of a body of water increases with depth, stable motions limited to the interior of the medium are possible. These motions sometimes have the character of waves but do not cause noticeable changes in the surface. The displacements caused by these waves in an isothermal surface have been measured in the ocean both with a bathythermograph and with thermocouples. Munk found waves of periods as short as a few minutes. Observations taken at three stations have shown that to a first approximation the waves are progressive with periods from a few minutes up to a few hours, lengths of a few hundred yards, and speeds in all cases of less than one knot. Stokes' theory of internal waves has been extended by Fjelstad to include any continuous distribution of density. An approximate solution with three linear gradients gives fair agreement with the observations. Movies taken by McNown, Rouse, and Munk at the University of Iowa will be shown.

* This work represents one of the results of research carried out by the University of California Division of War Research under contracts with the Office of Scientific Research and Development, Section 6.1, National Defense Research Committee, and with the Bureau of Ships, Navy Department.

C4. Reflection of Radio Waves from Tropospheric Layers. J. B. SMYTH AND L. G. TROLESE, *U. S. Navy Electronics Laboratory, San Diego.*—Variations in temperature and water vapor pressure gradients in the lower atmosphere markedly affect the propagation of high frequency radio waves. Reflection coefficients are calculated for an elevated layer produced by a warm dry air mass overriding a cool humid air mass. The index of refraction distribution is represented by a continuous function which permits the solution of the wave equation in closed form[1] if the influence of the earth is neglected. Experimental data taken over a 90-mile non-optical link on frequencies of 52, 100, and 547 megacycles per second are compared with theoretical curves.

[1] P. S. Epstein, Proc. Nat. Acad. Sci. **16**, 627 (1930).

C5. Attenuation of 1.24-Centimeter Radiation through Rain. L. J. ANDERSON, C. H. FRERES, J. P. DAY, AND A. P. D. STOKES, *U. S. Navy Electronics Laboratory, San Diego (Introduced by J. B. Smyth).*—The attenuation of 1.25-centimeter radiation by rain was determined experimentally over an optical path of 6400 feet. Nine equally spaced rain gauges were used to measure the rainfall intensity. The techniques used made it possible to use both uniform and non-uniform rainfall rates. Drop-size measurements were also made but no conclusions could be drawn because of the wide scatter in the drop-size distributions obtained. An average attenuation rate of 0.37 db/mile/mm/hr. was obtained. Previous theoretical calculations of the attenuation indicated that the rate of attenuation should be in the vicinity of 0.25 db/mile/mm/hr. The theoretical calculations were based upon completely incoherent scattering of the incident radiation by the rain drops. The observed discrepancy may possibly be due to a coherent component in the scatterers.

C6. Note on the Theory of Noise in Receivers with Square Law Detector. M. KAC, *Department of Mathematics, Cornell University,* AND A. F. J. SIEGERT, *Department of Physics, Syracuse University.*—While the response of a linear device (filter) to "white" noise is a Gaussian random function, the output of nonlinear devices—such as a receiver consisting of a linear *IF* amplifier, a square law detector, and a linear video amplifier—is a more complicated random function. In order to obtain the output voltage V as a sum of statistically independent terms—which makes the calculation of the characteristic function $\langle \exp i\zeta V\rangle_{Av}$ possible—we have expanded the input voltage in eigenfunctions of the kernel

$$\int_0^\infty K(t')dt'q(\tau_1-t')q(\tau_2-t')$$

where $K(t)$ and $q(t)$ are the response of the video and the *IF* amplifier to an infinitely short pulse. If both video and *IF* band width are small compared with the intermediate frequency, the eigenvalues of the kernel become doubly degenerate and the characteristic function is $\Pi_j(1-i\zeta\Omega_j)^{-1}$, where the Ω_j are the eigenvalues of the kernel. The probability density can then be evaluated by residues in terms of an infinite sum of exponential functions.

C7. On the First Passage Time Problem for a One-Dimensional Markoffian Gaussian Random Function. A. J. F. SIEGERT, *Department of Physics, Syracuse University.*—The probability density for the first passage time through zero for the one-dimensional Markoffian Gaussian random function (such as noise output of a RL circuit) has been given by Wang and Uhlenbeck.[1] To find the probability density $P(x_0/a\vartheta)$ for the first passage time through any value a, we obtain first the probability $f(x_0/a\vartheta)$ that, starting from $x_0<a$, the function $x(\vartheta)$ remains smaller than a for at least a time ϑ, using the normalized variables $x=(\beta/D)^{\frac{1}{2}}y$ and $\vartheta=\beta t$, with the other symbols defined in the reference. This probability is a solution of the adjoint to the Fokker-Planck equation with obvious boundary and initial conditions. Since $P=-\partial f/\partial\vartheta$ we find

$$P(x_0/a\vartheta)=\exp\frac{[(x_0^2-a^2)/4]}{2\pi i}\int_{-i\infty+\epsilon}^{i\infty+\epsilon}d\nu e^{-\nu\vartheta}\frac{D_\nu(-x_0)}{D_\nu(-a)}$$

where $D_\nu(z)$ is the Weber function defined in Whittaker and Watson, p. 349, and $0<\epsilon<\nu_1$ with ν_1 being the smallest root of $D_\nu(-a)=0$. For $x_0<a\ll-1$, P becomes a Gaussian with average $lg(x/a)$ and mean square deviation $(a^{-2}-x^{-2})$. For $a=0$ it reduces to the result quoted above.

[1] M. C. Wang and G. E. Uhlenbeck, Rev. Mod. Phys. **17**, 323 (1945).

C8. Multiple Master-Coincidence Method for Cosmic-Ray Studies.* VICTOR H. REGENER, *University of New Mexico.*—Negative pulses from individual Geiger counters are directly fed to the first control grid (grounded through a leakage resistor) of a miniature tube type 1R5 or 6BE6. The second control grid, which is grounded through a large resistor, receives a positive pulse from a master-coincidence unit through a condenser. This condenser, in conjunction with the large resistor at the second control grid causes, due to grid current, a long negative back-lash of the potential at the second grid, unless the first grid happens to be at a negative potential at the time the positive master pulse arrives. Thus, the plate current of the vacuum tube is cut off for a certain period immediately after each master pulse, except in case of a coincidence with a pulse from the individual counter tube. For indication, a small neon bulb is inserted in the plate circuit.[1] The resolving time can be reduced to 10^{-6} sec. The time of cut-off for the plate current can be lengthened to 0.5 sec., which allows photographic or mechanical recording. Any number of individual units can be connected to one master circuit. One miniature tube is needed for each individual Geiger counter.

* The major part of this work was done at the University of Chicago.
[1] V. H. Regener, Phys. Rev. **64**, 250 (1943).

C9. The Strengths of Some Model Magnets. STANLEY B. JONES, *University of California, Berkeley (Introduced by Wayne E. Hazen).*—A search was made for a magnet design suitable for cosmic-ray studies in airplane flights. The first two models were rectangular in shape and had solid poles, which necessitated a large air gap for observation of the cloud chamber. The first model was made with six one-inch cubes of Alnico V with boiler plate to complete the magnetic circuit. With a one-cubic-inch air gap, the

field strength was 1.90×10^3 gauss. The second model was of about the same design and had the same air gap but only four Alnico cubes and correspondingly less boiler plate. The strength was 1.51×10^3 gauss. The last two models were differently designed in order to utilize a split pole piece, which permitted a direct view of the chamber through the air gap. The direct view reduced the necessary length of the gap by about one-half. There were three cubic inches of Alnico in the third model and the field strength was 2.15×10^3 gauss. The fourth model, which was similar to the third, contained six cubic inches of Alnico and had a field of 3.35×10^3 gauss.

C10. Electron Collection in Ionization Chamber. RUBBY SHERR, *Los Alamos, New Mexico.*—With a parallel plate ionization chamber and a fast amplifier to reproduce the pulse resulting from electron collection, it is possible to measure the energy of an ionizing particle, and the angle which its path makes with respect to the electrical field of the chamber if the particles' path is wholly within the chamber. The initial slope of the pulse is a measure of the total charge in the track. As the electrons drift to the positive collecting electrode, this initial slope is maintained until the track strikes the collector. At this instant the slope starts to decrease, finally reaching zero when the track has disappeared. This time interval (of changing slope) is related to the length of the track and to the angle between the track and the field. By appropriate measurements on the pulse it is therefore possible to find the angle of the track as well as its energy for nuclear processes possessing an axis of symmetry (e.g., neutron scattering). This angle and the energy are sufficient to determine the process if the axis of symmetry coincides with the direction of the field. Tests, both photographic and electrical, have been made which verify the above conclusions.

C11. Force on a Conducting Tube Moving through a Magnetic Field. H. EKSTEIN, *Armour Research Foundation, Chicago.*—A long, thin conducting tube is moving in the direction of its axis through a stationary magnetic field B_0 which is cylindrically symmetric. The vector potential A, considered as a function of the axial direction Z, is represented as a Fourier integral. The Fourier mate of A can then be determined by the usual methods of integrating boundary value problems. In virtue of a theorem on Fourier integrals (Parseval's formula), the total force F on the tube can be calculated from the Fourier mates of the vector potential and the external magnetic field, without calculating explicitly the vector potential or the current distribution. An estimate of the force for the case of constant velocity is given. It is found that the force, as a function of the constant velocity v, has a maximum and decreases toward zero for higher velocities. The dependence of the maximum force on the physical constants is discussed.

C12. Pneumatic Heat Detector. HAROLD A. ZAHL AND M. J. E. GOLAY, *Signal Corps Engineering Laboratories, Bradley Beach, New Jersey.*—A pneumatic heat detector is described in which radiant energy is dissipated in a black absorber which is located in the center of a gas cell. The resulting heating and expansion of the gas serves to distort a collodion film located a few thousandths of an inch from a nearby parallel glass window. The distortion of the film is detected by observing a shift in a system of interference fringes formed by light reflected from the film and the adjacent glass surface. The principle lends itself readily to the design of systems comprising a multiplicity of heat cells and associated detecting films. A system utilizing 61 cells is described in connection with its use as a part of the first U. S. Army Radar, the SCR-268-T-1.

SUPPLEMENTARY PROGRAMME

C13. Magnetic Field with Small Axial Variation. CARL E. NIELSEN, *University of California, Berkeley.*—Magnetic fields commonly employed with cloud chambers are used over a small axial distance. Radial constancy of field is then desirable, but axial variations are of little consequence. Fields meeting these conditions are obtained either with an iron yoke and suitable pole faces or with Helmholtz type coils. In the magnet for the momentum measurement of slow electrons axial constancy of field is desired, and at the same time coil separation equal to the usable axial distance is required for illumination and photography. Although this result can be obtained with large radius coils, it is more efficient to use coils as small as permitted by the cloud chamber. They produce a field with a minimum at the axial mid-point; the minimum is then removed by the use of iron rings inside of the coils. Additional gain in uniformity and field strength is obtained from iron bars distributed uniformly around the coiled parallel to the axis. The resultant field is uniform within two percent throughout a cylinder 10 cm in diameter and 20 cm long; the field is 1300 oersted with 10-kw input power. It is worth noting that the gain in field from the iron is greater than would result from an equal additional weight of copper, hence it would be profitable to use some iron even if the coils were placed closer together as in the conventional cloud chamber arrangement.